Rommell.
ESSENTIALS OF ANIMAL BREEDING
Farmers Bul. 1167

FARMERS' BULLETIN - 1167
UNITED STATES DEPARTMENT OF AGRICULTURE

ESSENTIALS OF ANIMAL BREEDING

THIS BULLETIN is written in simple language for the man who breeds farm animals, who wants to learn the rudiments of the science of breeding, and how to apply them in practice. It sets forth some of the known facts regarding the operation of the forces of heredity. Controversial subjects are avoided so far as possible.

The reader who cares to go deeper into the study of genetics is referred to textbooks on the subject, and particularly to Department Bulletin No. 905, "Principles of Livestock Breeding," by Sewall Wright. It is published by the U. S. Department of Agriculture, and is obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 15 cents.

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief
Washington, D. C. November, 1920

ESSENTIALS OF ANIMAL BREEDING.

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CONTENTS.

BASIC FACTS ABOUT HEREDITY.

IN DEALING with the subject of heredity we must recognize clearly the following facts: First, animal and plant forms, as a rule, have developed gradually and very slowly, by very small changes; in short, by the process known as evolution. Second, whatever an animal has, so far as its inheritance is concerned, it gets from its parents—they get theirs from their parents, and so on clear back to the beginning; nothing was imposed from the outside. For the present, accept this fact without question. We shall try to make it clear later. Third, a very clear distinction should be drawn between the effects of inheritance and the effects of food and environment.

Every one who is at all familiar with domestic animals knows what a wonderful effect the food an animal eats has on its development, especially when it is young. It is also known that the younger an animal is the more readily it is influenced by its food. Now, from the very first moment that a young animal begins to develop, from the very instant that growth begins with the fertilization of the egg cell, it receives food from some source or it dies. When it is only a single cell it is being fed. If a young animal after birth is

NOTE.—In the preparation of this article, the writer received material assistance from officers of the Bureau of Animal Industry, especially Messrs. F. R. Marshall (now secretary of the National Wool Growers' Association), Sewall Wright, Dr. John R. Mohler, and Mr. D. S. Burch. He is also greatly indebted to Mr. Dewitt C. Wing, of Chicago, who made many helpful suggestions.

easily influenced by its food, how much more will the delicate little creature, known as the fetus or embryo, be influenced by the character of its food supply. A clear recognition of this fact will explain many occurrences which are often attributed to supernatural influences, and, at the same time, the breeder who recognizes this fact will not neglect proper attention to the nourishment and care of the pregnant mother as well as the nursing animal.

Accidents and disease also are important in their effects on the growing embryo. If an incubator is neglected on a cold night and the eggs become chilled, the hatch is seriously impaired and a large number of chicks are killed in the shell. If an in-foal mare is subjected to very heavy strains or forced to pull extremely heavy loads, the foal may be born too soon or even be killed in the womb. Contagious abortion may get into the herd without the owner's knowing it and cause the loss of a large proportion of calves. Heredity, however, has nothing whatever to do with any of these things.

THE SCIENCE OF BREEDING.

THE UNIT OF LIFE.

The smallest unit of life is the cell. A single cell is very small, usually of microscopic size. It is surrounded by a membrane, and each cell usually contains a nucleus—a sort of center of the things that go on in the cell. The animal body contains millions of cells, but those in which we are most interested at this moment are the cells from the union of which a new animal life begins. They are the germ cells. They contain the hereditary material which determines the identity of each individual and which is known as the germ plasm. This is the bit of life which passes down the line of descent with each succeeding generation. It appears in the mother in the egg cell, and in the father in the sperm cells. This material is composed of elements which seem to be handed on unchanged from generation to generation. Only a portion of the elements in the germ plasm of the parent goes into each egg or sperm, however, as is explained in more detail later. The element of chance enters to such an extent in determining which elements shall go into a particular germ cell that there may be a marked dissimilarity among individuals which are members of the same family. Even more important than the influence of food on the developing embryo and the young, growing animal is the operation of chance in determining the identity of the new life.

The cells from which all life starts are developed in the generative organs. The egg (the female cell) is developed in the ovary of the female; the sperm (the male cell) is developed in the testicle of the male. In mammals each female has two ovaries, one on

each side, situated in the abdominal cavity. Connecting the ovaries with the uterus are the Fallopian tubes. The uterus is the womb, the chamber in which the young fetus develops until it is ready for birth. The uterus connects with the vagina, through which the sperm is introduced into the uterus and down which the young animal passes at birth. The genital organs and the urinary organs have the same outlets from the body.

When an egg matures in the ovary it passes down the Fallopian tubes into the uterus. If no sperm is introduced, the egg is thrown off infertile. In female animals an egg matures at fairly regular intervals, and this corresponds with some exactness to what is known as the period of heat or œstrum.

The period of heat varies considerably in different species and in different breeds and individuals of the same species. It usually occurs at intervals of about three weeks. In mares it appears on the ninth day after foaling, lasting two or three days. In cows it appears in from three to four weeks after calving when the cow is not suckling a calf, and in from six to eight weeks if she is. The heat period lasts only about one day in cows. Sows come in heat three days after farrowing, and not again until a week after the pigs are weaned. In sheep, except for a few breeds, such as the Dorset, ewes in North America ordinarily come in heat only in the fall for a number of periods of two or three days each at intervals of from two to three weeks.

Females usually accept service only during the period of heat. It seems to make little difference when service is made, whether early or late in heat. As a rule, not more than one service is necessary during one period of heat to insure conception. After conception takes place, the female does not generally come in heat again during pregnancy.

Male cells, or spermatozoa, are carried in the seminal fluid. There is only one egg, as a rule, except in such animals as hogs, rats, and others, which usually have several young at a birth. There are, however, millions of sperm cells, but only one of them is needed or used to fertilize one egg. Let us now proceed to a consideration of the first step in the formation of the new life.

THE BEGINNINGS OF LIFE.

The life which results when two animals are mated has its controlling elements in the nuclei of the germ cells. These nuclei contain a substance called chromatin, represented by very minute bodies called chromosomes. Chromatin and chromosomes are found in all cells all over the body, and the number of chromosomes in each cell is the same for each species of animal. Except for the accessory

chromosome (which determines sex), they are always in pairs.[1] In many of the domestic animals and in man the number of chromosomes is between 40 and 48, depending on the species. Just why this number should be limited and invariable we do not know. It is no more remarkable, however, that each cell in the hog's body, for example, should have 40 chromosomes (which is the case) than that each normal hog should have four legs.

This is easily understood until we come to explain what happens when the egg cell is fertilized at conception. Obviously an egg with 40 chromosomes and a sperm cell with 40 chromosomes could not unite, because that would result in a cell with 80 chromosomes and only 40 is the rule. It just wouldn't work, any more than a pig with eight legs would work. Therefore, to prevent the doubling of the number of chromosomes at conception, nature puts the germ cells, both male and female, through a maturing process known as maturation, so that, just before the two unite, each has only half the normal number of chromosomes for the species, one from each of the pairs present before maturation.[2] When the two cells unite, therefore, the fertilized egg has the usual number of chromosomes carried by the cells of the species. *This process occurs only in the case of reproductive cells.*

When two animals are mated, what happens? The reproductive cells have gone through the maturing process and are now ready for union. The sperm cells are active and move around until they come into contact with the egg. Several may surround the egg, but only one unites with it. The membrane surrounding the egg cell is pierced by the head of a sperm cell. The two become one and the egg is now fertile. It needs only nourishment to become in time a full-fledged baby member of its race.

Food, of course, will have a profound influence on this little mite of life, but, so far as we know, the character of the resulting animal, its sex, its identity, and its individuality, whether it is to be white or black, long-haired or short-haired, ring-streaked or spotted, are now settled by the laws of life. This minute cell now carries in itself all the force of inheritance from all the ancestors behind it to the beginning of life on earth. Every champion you or I have known began his career in just this way. Many, many influences stepped in and had an effect on his subsequent development. Some of these are easy to determine, but others are so obscure that theories and fancies have grown up to explain them.

What value has this information for the practical breeder? Can he use it in making his methods more efficient? He can not use it

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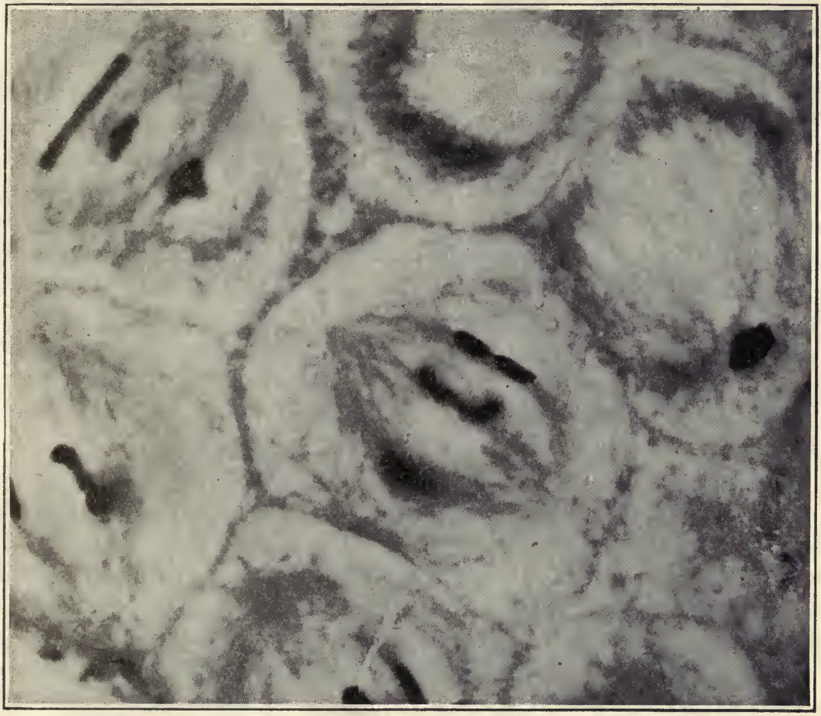
[1] For a discussion of the accessory or X-Chromosome, the reader is referred to textbooks.

[2] Biologists call this process *spermatogenesis* in the case of the male germ cells and *oögenesis* in the case of the female germ cells.

directly, but indirectly it can be most valuable to him, because it explains many things that otherwise are difficult to understand.

Suppose we are breeding animals in which the number of chromosomes is only four (two pairs). By the time both egg and sperm cells had gone through the maturing process, and the egg had been fertilized, 16 different combinations would be possible, some of them



What Chromosomes Look Like.
(Courtesy of Dr. E. E. Carothers.)

FIG. 1.—A remarkable photograph of a group of maturing male germ cells taken through a high-power microscope. The pairs of darkly stained chromosomes may easily be seen in two of the cells in the act of separating to form the nuclei of two new cells. Each of these resulting cells will have only half the original number of chromosomes and will thus be ready for union with a similarly reduced egg cell. Hereditary characteristics are transmitted in the chromosomes.

The factors which make up the identity of the chromosomes bear very much the same relation to heredity that atoms bear to chemistry.

no doubt differing very little from each other, but others having little mutual resemblance. In animals such as hogs, however, with 20 pairs of chromosomes in each cell, the possible combinations are almost infinite in number.[3]

These combinations are the results of chance. Here we have an egg with 20 pairs of chromosomes, about to mature. Twenty of these chromosomes only will be left when the egg is ready to unite

[3] The number of possible combinations in this particular case is 1,099,511,627,776.

with the sperm cell. What 20 will it be? Chance alone can tell, except that there will be one from each pair. Here comes the sperm cell, to mature which a similar process was gone through. Chance again determined that 20 out of the original 40 chromosomes should disappear and no determination can be made to show which 20 would prevail. But this is not all. The sperm cell does not come alone. It comes in swarms, but only one sperm cell penetrates the cell membrane and fertilizes the egg. What determines which of the thousands of sperm cells will be the one? Chance again.

The chromatin is the chief, if not the sole, determining factor in the development of the identity of the new individual, and the chromosomes are the agents by which this identifying process is carried out. When we think of the great number of combinations of chromosomes possible before fertilization is actually effected, we begin to understand why it is that members of the same family often do not look alike and why we have so many disappointments in breeding animals.

If chance is the sole factor in determining what chromosomes shall persist, where does intelligent breeding come in? Of what advantage is it to exercise care in matings? Why not leave it all to chance?

The simple answer to these questions is that we can lessen the probability of undesirable working of the laws of chance by increasing the uniformity of the chromosomes. That is done by careful selection to a certain type and by working with a group of animals whose ancestry is known. The highest examples of such methods are found in the work of breeders of purebred livestock where unbroken and known lines of descent run back for a great many generations, sometimes for 50 years or more on a single farm under the ownership of a single human family. The discussion of the subject of selection will be found under that heading later.

THE GESTATION PERIOD.

From the time the egg is fertilized, developments are rapid. The fertilized egg divides and subdivides with multitudes of subdivisions, until in time the embryo "begins to look like something," and we can make out the form of the animal and its parts. The time between the fertilization of the egg and the birth of the young animal is known as the period of gestation. This period varies with the kind of animal. The period for the common domestic animals is shown below, followed by a table to determine how long a time may be expected to elapse between service and birth. To make a practical application of the table count forward the correct number of days from the date of service.

Gestation period of various animals.

Mare	11 months (340 days).
Jennet	12 months (365 days).
Cow	9½ months (280 days).
Ewe	5 months (150 days).
Goat	5 months (150 days).
Sow	4 months (114 days).

Probable date of birth of young, female bred on first day of the month (Sewall Wright).

Date of service.	Probable date of birth.			
	Sow.	Ewe.	Cow.	Mare.
Jan. 1	Apr. 25	May 31	Oct. 7	Dec. 7
Feb. 1	May 26	July 1	Nov. 8	Jan. 7
Mar. 1	June 23	July 29	Dec. 6	Feb. 4
Apr. 1	July 24	Aug. 29	Jan. 6	Mar. 7
May 1	Aug. 23	Sept. 28	Feb. 5	Apr. 6
June 1	Sept. 23	Oct. 29	Mar. 8	May 7
July 1	Oct. 23	Nov. 28	Apr. 7	June 6
Aug. 1	Nov. 23	Dec. 29	May 8	July 7
Sept. 1	Dec. 24	Jan. 29	June 8	Aug. 7
Oct. 1	Jan. 23	Feb. 28	July 8	Sept. 6
Nov. 1	Feb. 23	Mar. 31	Aug. 8	Oct. 7
Dec. 1	Mar. 25	Apr. 30	Sept. 7	Nov. 6

Variations in the period of gestation for animals of the same kind are not readily explained. Some animals, such as sows, are quite uniform in the length of the gestation period. In mares there is a considerable variation. It has been suggested that in mares some time may elapse between the moment of service and the actual fertilization of the egg by the sperm cell. In guinea pigs the size of the litter affects the period of gestation, the period being shorter for a large litter than for a small one. The health of the mother during pregnancy also has an effect.

During the gestation period the young animal is carried in the mother's womb and is not connected directly with her body. The blood vessels and nerves of the mother do not connect with those of the growing embryo, but from the start the little one has its own little system of circulation and its own nervous system. It is carried in an enveloping sac which is attached to the wall of the mother's womb by buttons (cotyledons) which become detached when the time comes. The young are nourished by blood passing from the mother's body through the walls of the uterus into the sac in which the fetus is carried, and thence into the body of the young animal by transfusion, much as water would pass into a paper sack if you should lower it into a bucket of water.

INCUBATION PERIOD IN BIRDS.

In birds the incubation period corresponds to the gestation period in mammals. The period which elapses from the time eggs are put on to hatch until the chicks emerge is shown below. Young birds are nourished in the embryonic stages of their development by absorbing from the yolk the nutriment needed.

Incubation period of various birds.

	Days.
Goose	30
Duck	28
Turkey	28
Guinea fowl	25
Chicken	21
Pigeon	17

Much may be learned by any one of a studious nature by careful observations of the development of the embryo of chickens. The germinal disk may be plainly seen even in a fresh-laid egg, which, whether fertile or not, looks the same to the naked eye. When put into an incubator, however, the fertile egg begins to develop rapidly, and the transformation in the brief period of three weeks is wonderful. The course of this development in fertile eggs can be distinguished easily from day to day by the familiar process of candling eggs, or it can be studied in detail by carefully breaking the eggs into a saucer.

DETERMINATION OF SEX.

As the growth of the embryo progresses, sex becomes apparent. Sex seems to be determined by one of the chromosomes, and is probably settled at the time of conception.[4] The determination of sex is therefore a matter of chance over which the breeder probably has no control. For practical purposes, the breeder will find that, over a period of years, he gets nearly equal numbers of both sexes.

FECUNDITY.

The subject of fecundity is of great practical importance to breeders of animals. Fecundity depends very largely on the number of eggs which are matured at a given time by the female. Animals in which multiple births are the rule (of which sows are a common example) not only mature a considerable number of egg cells at one period of heat, but each one is fertilized by a separate sperm cell. In some cases, however, the fertilized egg may divide and twins or a larger number of young result. Such twins are known as identical twins, and are usually of the same sex, with very strong

[4] See note (2) page 6.

points of similarity. Young from multiple births, resulting from the fertilization of different egg cells, show as wide a difference in individual characteristics as young resulting from separate births. The most prolific of the common domestic animals are the birds. The domestic hen may lay more than 200 eggs in a single year.

The common practice of British shepherds, known as "flushing" ewes, has been claimed to increase the proportion of lambs in the flock. This practice consists in giving the ewes an increase in their feed, both grain and succulent pasture, so that they are gaining in weight and condition at breeding time. No exact scientific data have been available until recently, when Marshall and Potts, of the Bureau of Animal Industry, conducted experiments which confirmed the correctness of the British practice. They also have evidence which indicates that the success of the practice depends on cutting off the grain ration and putting the ewes on short pasture as soon as they are bred.

What a Good Mother Can Do.

FIG. 2.—The ewe at the right was lambed in March, 1914. She was a prize winner as a yearling and as a two-year-old. Her first lamb was a ram dropped in 1916. Since then she has had seven lambs. The other two ewes are her twins of 1919 and were shown in the trio for Hampshire ewe lambs, winning first prize at the 1919 International Live Stock Exposition. The lamb at her side is her 1920 contribution to the wealth of America's purebred livestock industry.

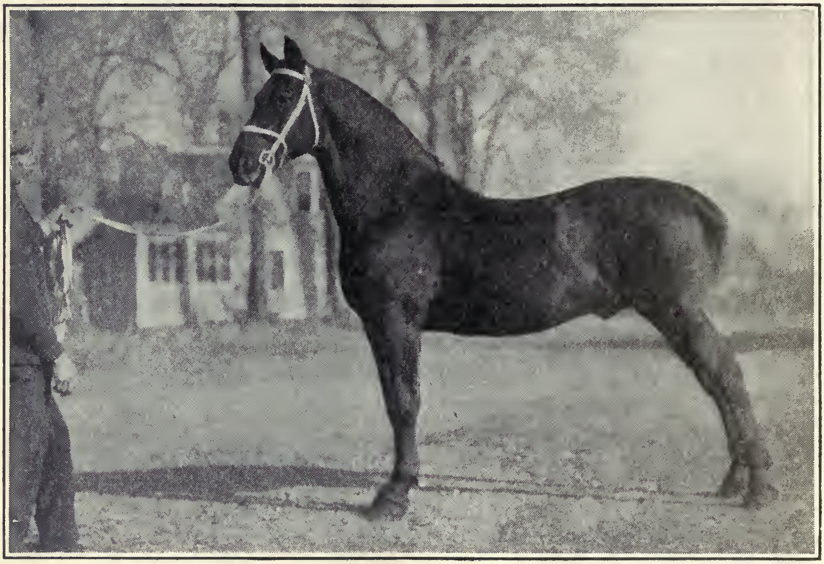
The rules or laws of the inheritance of fecundity are not all known, but to some extent it is dependent on inheritance from the mother; therefore, the selection of females which have a tendency to produce a large number of young at a birth will tend to increase the returns from the flock or herd. This is of practical importance in the case of hogs, sheep, goats, and poultry. Twins in cattle are objectionable unless of the same sex. When a heifer is a twin with a bull calf, the heifer is known as a "freemartin" and in the majority of instances is sterile.

PREPOTENCY—MENDEL'S LAW.

Prepotency is the power of an animal, male or female, to stamp its characteristics on its offspring. If this ability is handed on to sons

and daughters, we say that the stock "breeds on." In rare instances an animal, usually a male, is found, which has such power as a breeder that it leaves an indelible impress, even to the extent of becoming the fountain head of a new breed, such as the stallions Justin Morgan, Hambletonian 10, and Denmark.

Most of the cases of prepotency which the breeder usually meets with are probably instances of the operation of what is called Mendel's law. A clear explanation of this great law of heredity can not be made within the scope of this short article, and the interested reader, if he cares to go into the subject in detail, is referred to Dr. Wright's bulletin.[5]



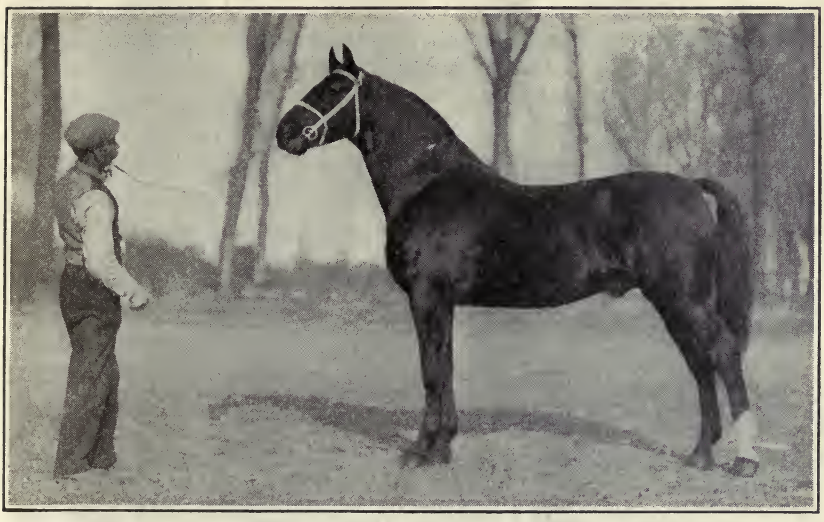
How Good Blood "Breeds on."

FIG. 3.—Carmon, Standardbred stallion at head of United States Government stud, Buffalo, Wyo., a horse which has been remarkably successful in stamping his characteristics on his offspring. Photograph taken when Carmon was 20 years old.

It must be pointed out, however, that most operations of heredity are not simple; on the contrary, they are highly complex and often extremely difficult to understand. The chief use which the practical breeder of domestic animals can make of Mendel's law at this time is to find in it an explanation of occurrences that otherwise have no rational explanation.

One of the most interesting applications of Mendel's law in cattle breeding is the inheritance of the polled characteristic. If we breed a horned cow to a Red Polled, Galloway, Angus, or other true polled bull, the chances are 9 to 1 or better that we shall get a polled calf. The white face of the Hereford appears to be a similar instance.

[5] U. S. Department of Agriculture Bulletin 905, "Principles of Livestock Breeding."



How Good Blood "Breeds on."

FIG. 4.—Albion, one of Carmon's first sons used in the Government stud as a sire. Note the remarkable resemblance between this horse and Carmon. Photograph was taken when Albion was nine years old.

How Good Blood "Breeds on."

FIG 5.—Defender, son of Albion. Photograph taken when Defender was six years old. Note that the type has been handed down from grandfather to grandson.

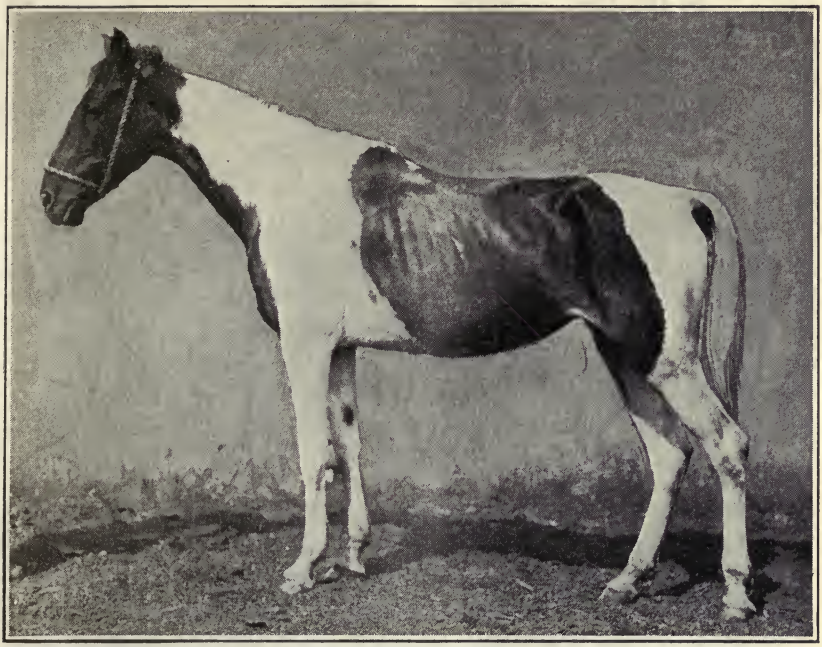
If we breed a common cow to a Hereford bull, we get a calf with a white face. We say, therefore, that polled breeds are very prepotent so far as "taking the horns off" is concerned, and that the Hereford is prepotent in putting a white face on his calves. This may happen either way; that is, polled bull and horned cow, or horned bull and polled cow, Hereford bull and plain-faced cow, or plain-faced bull and Hereford cow. The temptation is to make great claims for the prepotency of the breed as a whole on the evidence of one or two points only. For see what happens when we mate a Hereford with one of the polled breeds. Then we get a polled, white-faced calf.

How Bad Blood "Breeds on."

FIG. 6.—A spotted stallion of nondescript breeding used extensively as a sire in the community where he was owned. Note not only the bad color, which is almost unmarketable, but also the curby hocks and generally mean appearance.

These points are not prepotency at all, but manifestations of Mendelian "dominance." The polled character is dominant over the recessive horned character, and the white face over the recessive plain face; but these cases do not necessarily indicate that the animal is particularly prepotent in other characters of much more practical importance. The same rule seems to apply in the inheritance of the black color in sheep, black acting apparently as a recessive to the usual white color. It can readily be eliminated by culling out the black lambs.

A great many data have been accumulated as to the characters in animals which illustrate the operation of Mendel's law, but



How Bad Blood " Breeds on."

FIG. 7.—A daughter of the spotted stallion. Observe crooked hind legs, as well as bad color.

How Bad Blood " Breeds on."

FIG 8.—Another daughter of the same stallion. Note how the curby hocks have been transmitted and how there is also a striking tendency for the spotted color to prevail. Some of the stallion's bad qualities appear in the forelegs on this individual.

apart from the horns of cattle, coat color, eye color, and the like, the application of this law to livestock breeding has a long way to go before its principles are adaptable to practical use by breeders. It is fairly certain, however, that many of the obscure happenings in animal breeding are really manifestations of Mendelism. Most cases of atavism ("throw backs" to a remote ancestor), for example, are probably Mendelism in practice.

The animal structure is so diverse and complicated that the determination of the application of Mendel's law to the inheritance of the characters which affect the commercial value of domestic animals is a task of tremendous magnitude. Great progress has been made in laying the foundations for the scientific study of animal breeding by working out the principles of this law, and we may expect still greater progress in the future. Biologists who are studying heredity have their faces set in the right direction. The accomplishments of the last twenty years in the study of heredity have taken this subject out of the field of guesswork, and for this service all animal breeders are under obligations to Mendel and his disciples.[6] If, by skillful selection and intelligent breeding methods we can get results of permanent value; if, with the present knowledge, we can make real progress in animal breeding, we can afford to wait for the more definite working out of Mendel's law, with the assurance that this law controls the mechanics of heredity in domestic animals and that any practical application of it to animal breeding will add to our store of useful knowledge and to the efficiency of our breeding methods.

Fig. 9.—Purebred Hereford sire, scrub dam, and offspring. Note how the characteristic markings of the Hereford sire, especially the white face, are transmitted.

[6] The discovery of this law by the Austrian monk, Gregor Mendel, in 1865, its virtual disappearance for 35 years and its rediscovery simultaneously by several investigators working independently, form one of the romances of science. Mendel's papers attracted very little attention when published, owing, no doubt, to the intense interest of the world in the researches of Darwin. Mendel died in 1884 without realizing the importance, to humanity, of the work which he had done.

THE ART OF BREEDING.

SELECTION.

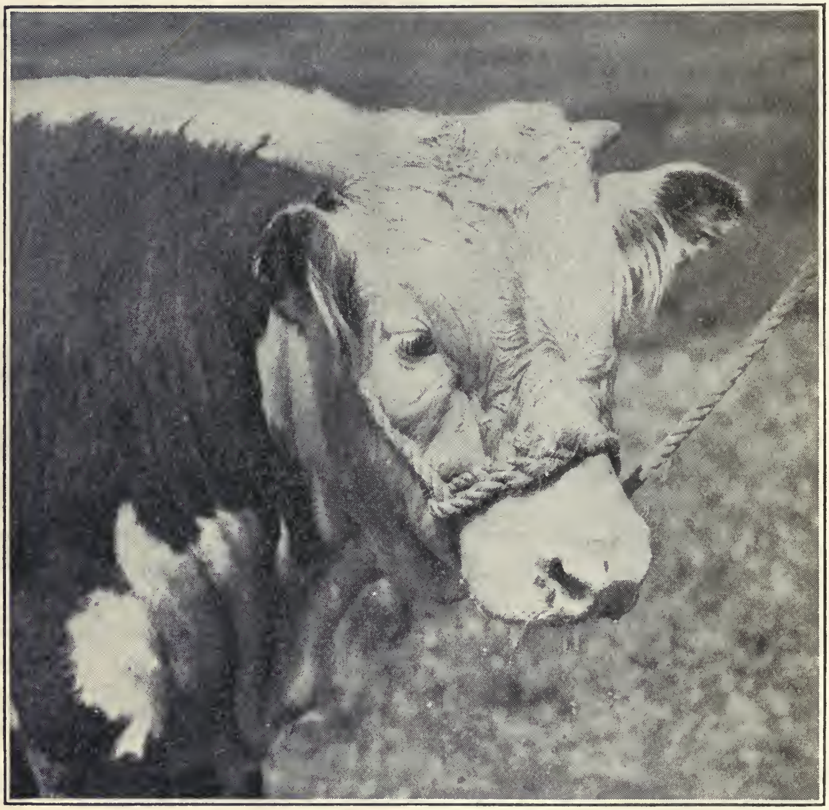
Keeping in mind the principles laid down in the foregoing pages, it is clear to every one that in order to make the best out of the hereditary material represented in one's herd, and to use the laws of nature to the best advantage, one must have clearly in mind a standard which he sets for himself as the ideal toward which he must work. This standard must be definite and should be as practical and simple as possible. The exercise of selection, wisely and judiciously pursued, offers the breeder one of the two most effective means of bending to his own purposes the operations of chance, which otherwise nature will use to his confusion and undoing.

We have made the statement already that the hereditary material is passed down from generation to generation without change except so far as the operation of the laws of chance may have affected the process, beginning with the maturation of the germ cells. It is plain, however, that constant selection of a good type will increasingly intensify the properties of a given set of characteristics (in other words, of a definite type), but that this selection must be pursued constantly because the chromosomes which tend to produce the less desirable types continue to be present, although in decreasing numbers. If the force which has been selecting the desirable chromosomes is removed, then the undesirable ones may once more prevail. In other words, our modern breeds of farm animals are an improvement over the stock from which they sprang. There is, therefore, a constant pull backward and downward against which the breeder must work by wise selection and skillful matings. If this intelligent direction by human skill should be removed, our animal stock would rapidly degenerate to the level of the types of centuries ago.

Selection should be designed to correct faults in the parents, and, as a rule, the male is depended on to do it. A few concrete cases will illustrate. If the females have a tendency to be too leggy, select a male that is compact and close to the ground. If the backs are not ideal, select a male with an exceptionally strong back. If the sow's feet are not the best, get a boar that is unusually strong in his feet with strong, upright pasterns. We might multiply these illustrations indefinitely. Therefore, a sire should be a better individual than the females with which he is to be mated; otherwise the standard of the herd or flock may decline. To some extent a breeder may extend these principles to the grandparents, but for practical work on a farm that is producing market stock it is commonly unnecessary to go farther back than the sire to be selected. In other words, don't

buy a poor male merely because some one tells you he has a good pedigree.

The breeding animals selected should look the part. Good bone; deep, broad chests; strong, broad backs; and fully developed bodies should be emphasized. Especial attention should be paid to the head, for that part of the body tells many a story which otherwise would be overlooked. Width between the eyes, full, prominent eyes of pleasing appearance, broad muzzles, and prominent nostrils indicate



Hereford Calf Illustrating Character.

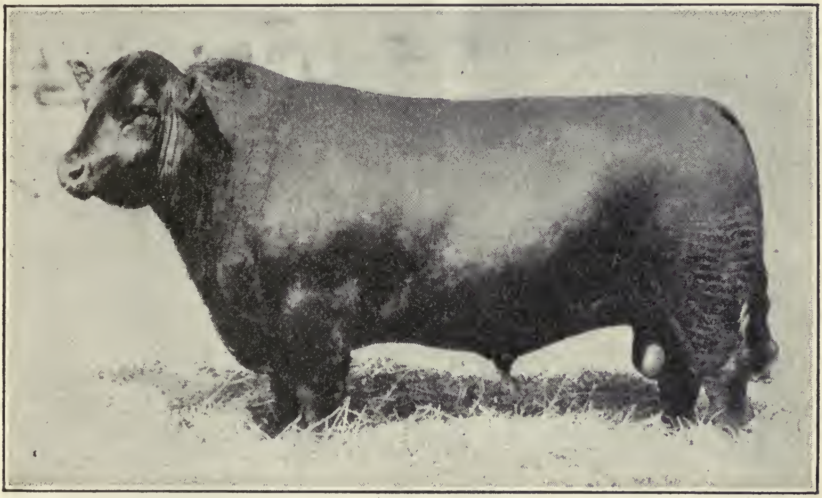
Fig. 10.—Compare this picture with those of other bulls shown. Each one shows strong masculinity. Each one has an individuality as marked and striking as the individuality shown in photographs of human beings.

points of value both to the breeder and the feeder. In males, strong evidence of masculinity is important. The evidence of the masterful impressiveness of the masculine sex is often apparent in very young animals and may be taken to indicate a youngster that with proper feed and care will grow out into an impressive sire. In females we look for femininity, without indications, however, of weakness of constitution. Avoid cows, for example, with heads like those of steers. These points make up in total what breeders call " charac-

ter" and are among the most important considerations which a breeder must bear in mind in building up his herd or flock.

Good feed, care, and attention are valuable adjuncts to selection. Unless feeding permits full development we can not select intelligently the animals which have received and can transmit the characters we desire to perpetuate. Starved animals which never have had an opportunity to demonstrate their capacity to produce meat, milk, wool, or other valuable commercial products, furnish poor material from which to select individuals capable of maximum and most economical production.

One must use these rules of selection with judgment and common sense. While faults undoubtedly can be corrected by the use of



Idolmere.

Fig. 11.—Grand champion Aberdeen-Angus bull at the 1919 International Live Stock Exposition. One of the greatest bulls of the breed ever seen in an American show ring. An exceptional photograph of a great bull showing not only splendid beef conformation but outstanding breed character also. Note especially the strong character as shown in the head and neck, as well as the great length of the bull and his remarkable smoothness.

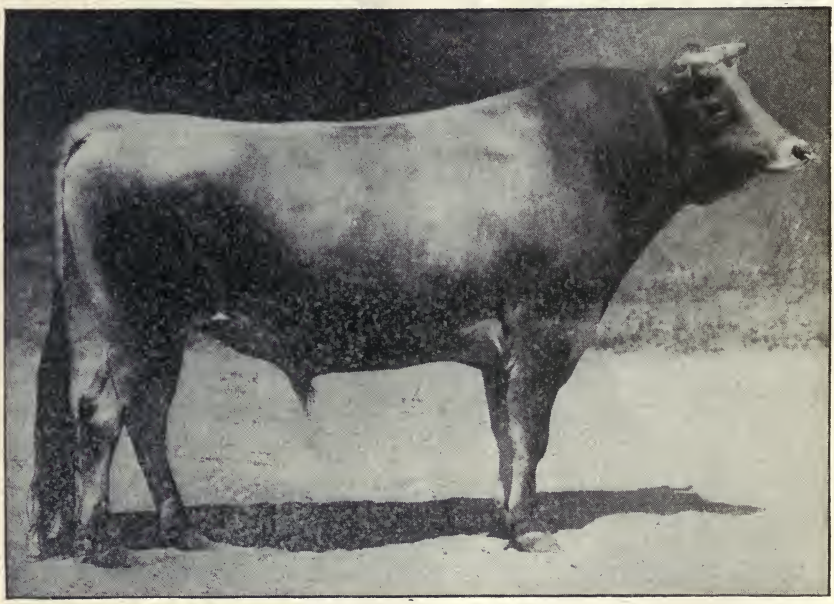
males of superior individuality, it may be unwise to use some females for breeding even market stock because they may be too inferior for even this purpose. To sell them and substitute better individuals, either high grades or purebreds, is often the more sensible course and the more profitable in the end.

Selection alone, however, is not certain to result in steady progress. Different combinations of hereditary elements may result in apparently the same characteristic. In practicing selection a man may introduce at any time the blood of a line which merely looks like that of his own stock, but which breeds differently. The result is the undoing of past progress, the next generation showing the vari-

ability characteristic of the second generation of a cross. Only by breeding within relatively narrow limits can one be reasonably sure that he is mating animals which both look alike and have the same heredity.

INBREEDING.

Next in importance to selection as a means of improvement in breeding animals, the most effective process at the command of the breeder is the judicious mating of related animals. This process is known as inbreeding, and various terms, such as line breeding, close breeding, and incestuous breeding, have been used to define varying degrees of intensity of the process.

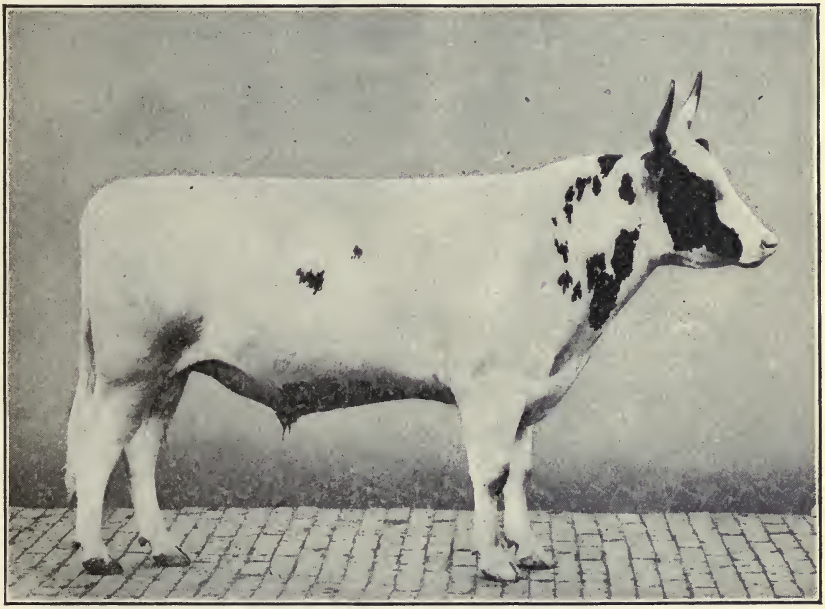


Jersey bull, Pogis 99th of Hood Farm No. 94502.

FIG. 12.—Animals such as this one show strong evidence of breed character, masculinity, and impressiveness.

Inbreeding is one of the most discussed subjects in the whole field of genetics. All sorts of bad results are attributed to it. Lack of vigor, nonresistance to disease, decline in size and fecundity, and even sterility are the fate of inbred animals, in the minds of many people. These ideas have a certain basis in fact, and often extend to farmers, who sometimes refuse to buy males which have inbred pedigrees. Breeds and families which have been intensely inbred for several generations develop manifestations of constitutional weakness which, it seems, can be explained only on the grounds of their close relationship. Scientific data of exact and elaborate scope, worked out under controlled conditions, are not abundant on this point.

We have, on the other hand, the accepted fact that progress in animal breeding began only when breeders began to inbreed. The work of Bakewell, who experimented during the last half of the eighteenth century, which made the greatest impression was the methods he used, and the method that has been most far-reaching in its results was that he mated his animals with first regard to their individual suitability for the mating, and with secondary importance placed on their relationship. Since the time of Blakewell every breeder who has made an impress of permanent importance on his breed has used inbreeding as his most useful working tool.

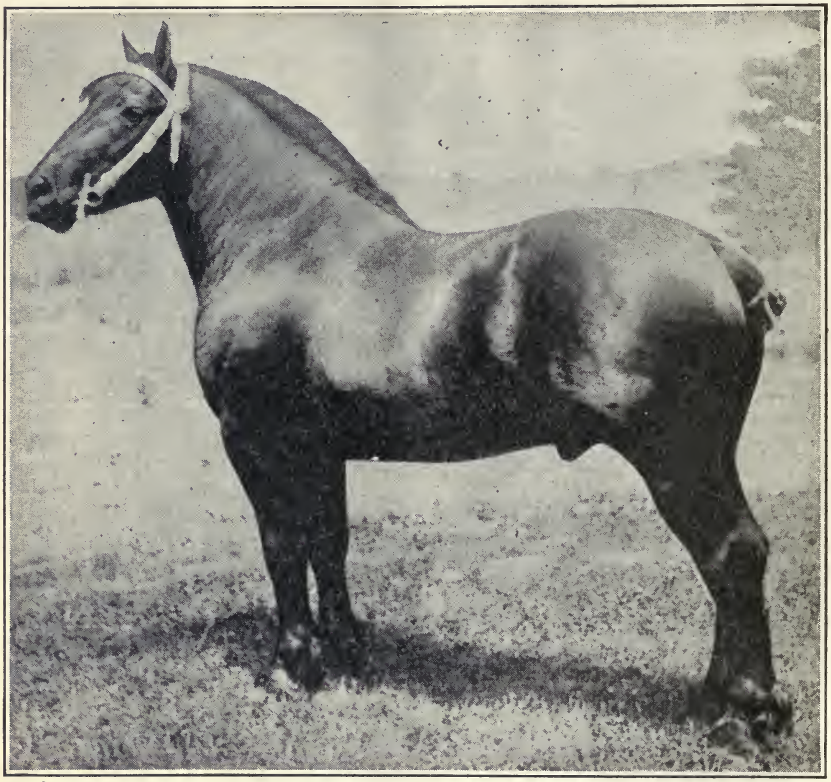


Purebred Ayrshire Bull, Hobsland Perfect Piece 16933. (Senior Grand Champion Aryshire Bull. National Dairy Show, 1914.)

FIG. 13.—A good breeding animal impresses the observer in many ways. The pose of this bull, his lines, and the sweep from the head to the tip of the tail give an unmistakable impression of individuality, power, and merit.

When we mate related animals we are bringing together animals with a more nearly uniform character in their hereditary material than when we mate those that are not related. We are, therefore, increasing the probability that the offspring will be like the parents. But there may be hidden in the hereditary material the factors of an undesirable character. In other words, we may not know all that we should know about the ancestors. Back somewhere, perhaps, was a bad one whose traits are being bred out by selection in each successive generation. If we mate two related animals carrying this defect, we greatly increase the chance of perpetuating it. Instead of having an even chance or better of keeping the defect under

subjection by not inbreeding, we double the chance of its appearing when we do inbreed. It seems possible to inbreed some animals much more intensely than others, and certain strains of breeds in the same species exhibit similar traits. To cite specific instances, cattle which have a special susceptibility to tuberculosis, horses with a tendency to certain unsoundness, such as roaring or spavin, should not be inbred. The safe rule, therefore, is not to mate closely related animals which have the same defects, either themselves or in their immediate ancestors.

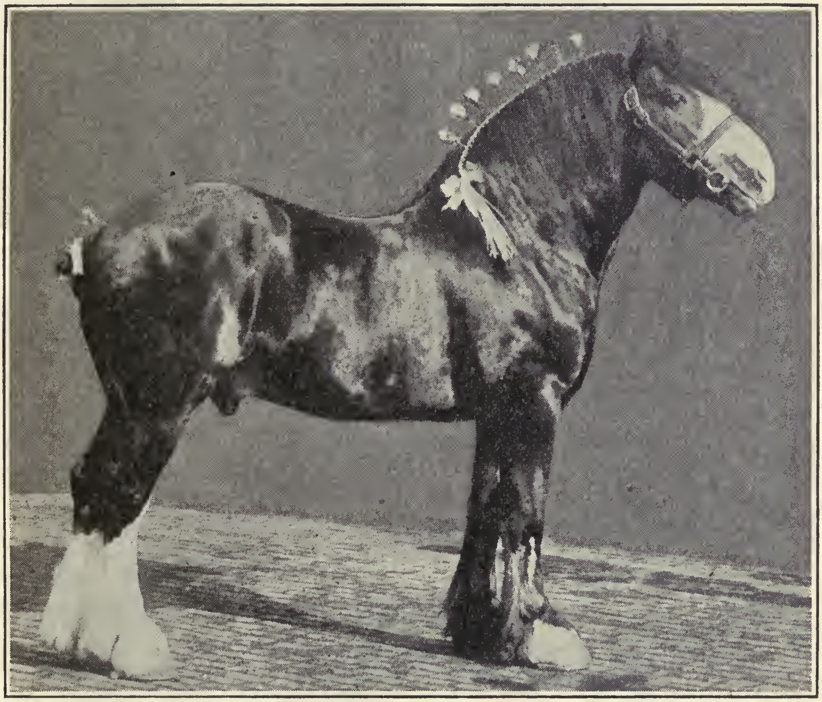


Percheron Stallion, Dragon.

Fig. 14.—Descendant of a long line of impressive ancestors and himself a sire of valuable draft horses.

Inbreeding should be practiced only by the most skillful breeders, and by them only when they have definite knowledge of the ancestry. Judiciously used, inbreeding results in a rapid fixing of type and enables the breeder to obtain results much more rapidly than without its use. It is like any other high-powered implement. Properly used, it is a wonderful adjunct to human efforts; in the hands of the ignorant and careless it is a source of danger.

The purchaser of inbred males, however, need have no fear of using them if they are creditable representatives of the breed. As a matter of fact, he should prefer inbred males to others, especially if they are not related to his females, because they are more nearly alike in their hereditary material, and for that reason more likely to reproduce themselves with uniformity. They are usually sold under a guaranty that they are breeders (or they should be so sold), and if they do not breed, any reputable breeder will replace them. It is a general rule that inbred animals, when mated to unrelated ones, even though



Clydesdale Stallion, Fyvie Baron.

FIG. 15.—Note intelligent head and strong, crested neck, as well as evidence of vigorous constitution, indicated by depth of body.

the latter themselves are inbred, produce offspring larger and more vigorous than either parent. From every standpoint, therefore, an inbred sire should be desirable to use in a farmer's herd, provided the animal is a good individual. The farmer should make certain of this fact. Then he should ascertain that the strain itself is vigorous, and finally he should have a guaranty that the animal bought will prove to be a breeder. If these conditions are met, the farmer will find inbred males much more impressive and will have a much more rapid return in improving his stock than if he had used males which were not inbred.

Whether a breeder should or should not inbreed his stock is a matter which he must settle for himself. The successful use of inbreeding is one of the best tests of a breeder's skill, and no man should inbreed unless he is confident that he possesses the requisite skill to make such a step successful. Generally speaking, the inbreeding of market stock is unwise; but the use of inbred males on the females of such a stock may be of the highest value, provided the breeding establishment which produced the males has not been injured by inbreeding. Such a fact can be readily ascertained.

Inbreeding fixes characters which can be fixed, but one of its most valuable consequences is bringing clearly to light the relative merits of different strains in such characters as fecundity, resistance to disease, and the like, which are affected so much by factors other than heredity that they can not be fixed in individuals. In these cases progress is more likely to result from selection of strains than from the selection of individuals.

A real danger from inbreeding is not to be urged against the practice itself, but against the peculiar infatuation which breeders acquire for certain bloodlines. Once let a given line of breeding demonstrate its excellence for the production of a certain valuable type, and every progressive breeder strives to acquire some of this valuable blood. The strain soon becomes "fashionable." From this stage to breeding for the pedigree rather than for the animal is an easy step which is taken much too often. The corrective for such methods is the show ring, with competent and fearless judges in authority.

OUTCROSSING.

Quite the converse of inbreeding is the practice of outbreeding or outcrossing. Even in plants which are usually self-fertilized, nature has provided for an occasional outcross that materially increases the vigor, stamina, and general well-being of the stock. In animals which have been intensely inbred, outcrossing has interesting and important results. Mating to stock which has not been inbred results in increases in size and vigor. A similar result also follows the mating of two strains, both of which have been inbred, but which are not closely related to each other.

PURE BREEDING.

Step by step we climb the ladder of the art of breeding until we finally reach the top in the breeding of purebreds, the most fascinating, the most inspiring, and the most remunerative branch of animal breeding when successfully followed; the most difficult and the most disappointing when not successful. The successful breeder of this class of animal is far more than a business man or a farmer. He is an artist, and the artistic appeal is first in importance to him.

The basis of pure breeding in the United States, except in the case of poultry and pet stock, is pedigree registration. Animals must be not only purebred, but they must be registered in the book of record established for the breed.

Standards in pure breeding are more exacting and more complicated than in breeding solely for the production of meat, wool, milk, or eggs, but they should be practical, because the proof of the practical value of a breeder's work is the demand which is sustained in the long run for his breeding animals. The surplus of the registered purebred establishments goes to improve the native and unregistered grade herds and into purebred herds of less merit. A high standard is therefore absolutely essential to maintain quality, average excellence, and the reputation of the herd. Practical ideals must have quite as much weight as purely commercial considerations in the determination of the standards.

A breeder's success depends to a very large extent on his ability as a qualified judge of animals, on his knowledge of the pedigrees of his animals, and on his acquaintance with the characteristics of the ancestors of those animals. The breeder's ability as a judge must be based on an instinctive gift to recognize animal types and carry them clearly in mind. This is of even more importance than a knowledge of pedigrees, because a knowledge of pedigrees is of practical value only as it gives its possessor an acquaintance with the individuality and type of the ancestors in the pedigrees, which he may use in making effective matings and thus perfecting the type of his animals. One of our most eminent breeders of hogs once made the statement, "I breed my hogs in the barnyard, with the animals before me, not in my parlor with their pedigrees before me." That homely statement carries a truth which every ambitious young breeder should follow. Before deciding to make a certain mating, the man who made this statement is said to spend hours studying his breeding animals, going over their characteristics, and especially recalling to mind the characteristics of their parents, grandparents, and more remote ancestors. If this review is satisfactory, the mating is made; if not, some other is tried.

To sum up, knowledge of a pedigree must not stop with the routine knowledge of the names of the animals which compose it. The breeder must know also the characteristics of these animals, as far back as possible, their weaknesses as well as their strong points. When he possesses this information the breeder can more intelligently mate individuals and blend bloodlines. He has then a practical working knowledge of pedigrees. The study of pedigrees, therefore, based on a knowledge of the characteristics of the animals composing them, is indispensable to the man who would excel as a constructive breeder.

THE VALUE OF A PEDIGREE.

No one breeds animals without dealing with pedigrees. The common phrase "pedigree stock," as a synonym of "well-bred" or "purebred" in describing livestock, is a misnomer. All plants, all animals, all people have pedigrees, but all information about these pedigrees is not available. Pedigrees become known because of merit in some individual which stands out above his fellows.

The Sire of a Grand Champion.

FIG. 16.—To achieve the highest results in livestock production pure blood is most likely to result satisfactorily. Illustration shows the Shorthorn bull, Lavender Sultan, sire of the three steers shown in figure 18. This bull is a remarkably impressive sire with wonderful thickness of flesh. Note how his thick flesh is transmitted to his sons. Compare this picture with figures 17 and 18.

His progeny are watched, and if they have merit above the average they are "saved for breeding purposes," and by and by we have a line of known descent and ultimately perhaps a pedigree of distinction and formidable appearance. They are written into genealogies, herdbooks, flock books, and studbooks, and the inheritance of decades and even of centuries becomes in time a matter of written record.

The proof of the value of the pedigree itself is the worth of the animals it produces. The value of animals with certain pedigrees

depends upon their ability to produce desirable types with greater excellence and uniformity than animals with other pedigrees or

The Dam of a Grand Champion.

Fig. 17.—Merry Sempstress, dam of Merry Monarch, the grand champion steer at the International Live Stock Exposition in 1919. Note not only her beef conformation but her good feeding qualities, clearly indicated in a head which is almost an ideal feeder's type, as well as an ideal breed type. She shows excellent indications of real feminine character.

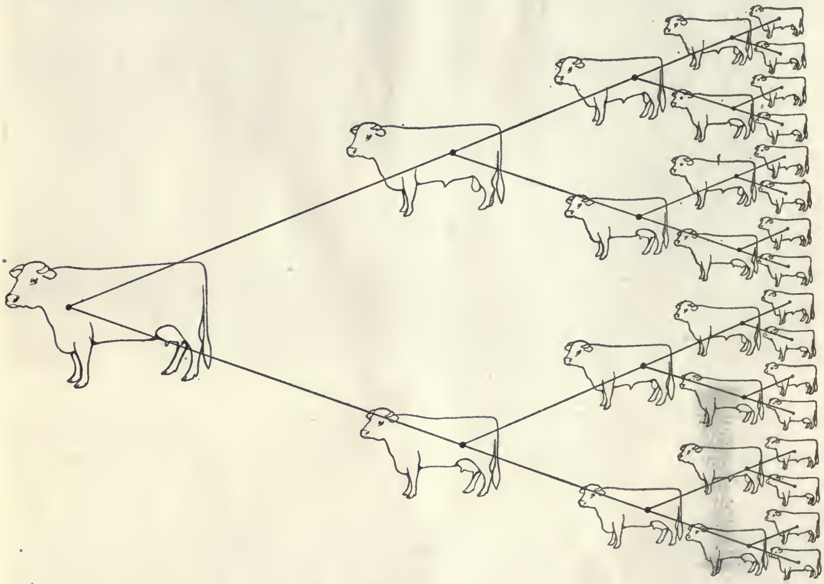
A Triumph of Breeding and Feeding.

Fig. 18.—Merry Monarch (right), grand champion steer at the 1918 International Live Stock Exposition, and two other prize-winning sons of Lavender Sultan. Compare with figures 16 and 17.

with no known pedigrees whatever. The power of the animal with a known pedigree to reproduce its type has been intensified by selection. Therefore, if the matings which have been made in constructing the

pedigree have not been directed by a high order of skillful selection, the animal may have intensified powers of producing an undesirable type, and may be what is commonly designated a "scrub purebred." The purchase of an animal or its use for breeding purposes solely on account of its pedigree is a dangerous matter and may result in much more harm than good.

What is the most important part of the pedigree? Usually only the ancestors which are "close up" are those which are of practical importance in determining the identity of the individual. Assuming that Mendel's law governs animal inheritance, we may occasionally



The Main Points of a Pedigree.

FIG. 19.—A graphic representation of the relative importance of ancestors in the first four generations. Families in livestock often trace their foundation to a single animal which may not be reached within ten generations. It is quite as important to know what sort of animals make up the later matings as it is to know to what family the animal belongs. The proof of the value of a pedigree is the worth of the animals it produces.

expect to find an off-type occurring, but by the repeated culling out of such types the frequency of their occurrence is being constantly reduced. Therefore, if we are sure of the parents and know what is in the first three or four generations of an animal's pedigree, we know the most important facts about that pedigree. In generations beyond the third or fourth the influence of any ancestor is so slight that for practical purposes it may be ignored.

In a four-generation pedigree there are 30 ancestors, all of which may be different individuals. Usually in pedigrees of most purebred herds there are fewer than 30 separate individuals, depending on the amount of inbreeding in the pedigree. The chart (fig. 19) shows this

fact graphically. Suppose there is no inbreeding in a four-generation pedigree, the chance that one of the animals in the fourth generation will dominate the pedigree above all others is very small indeed. The chart thus shows graphically the relative importance

Grading Up With Sheep.

FIG. 20.—The ewe at the left is a Mississippi Piney-Woods native. The lamb is her produce by a purebred Shropshire buck. At four months of age the lamb outweighed not only her mother but any other ewe in the flock. Note the absence of wool on the belly of the ewe and the good, thick, uniform fleece of the lamb.

of the respective ancestors for four generations. Each figure in the chart is just half the size of the one in the generation preceding, and this conforms fairly well to the standard formula of inheritance.

The chance of grandparents' dominating the inheritance of the mating can not be more, and is undoubtedly much less, than 1 in

Grading Up With Dairy Cattle.

FIG. 21.—The result of 15 years' consistent work with purebred bulls. A Mississippi grade Jersey herd bred up from a native foundation.

6; the chance of a great-grandparent is less than 1 in 14; and the chance of a great-great-grandparent (fourth generation) is less than 1 in 30, provided no inbreeding occurs. In a pedigree covering 10 generations (which can easily be run out with almost any of our well-established breeds of domestic animals) there are 2,046 ancestors, more than half of which are in the tenth generation. Yet cattle are sometimes sold at a premium because a certain cow appears in the pedigree as far back as the tenth generation or even further, regardless of the merit of animals much further down in the pedigree. Or a pedigree may be classed as unfashionable and the animal carrying it may be discriminated against, regardless of its individual excellence, because some unpopular animal may have appeared in an extremely remote generation.

Value of Pure Blood.

FIG. 22.—In 1915 the Bureau of Animal Industry purchased on the Washington (D. C.) market a flock of mongrel hens. These hens were mated to standardbred males to show how mongrel flocks could be improved by grading up. This illustration shows a mongrel hen, and the four which follow show the results of the demonstration with purebred Barred Plymouth Rock males.

LIVESTOCK IMPROVEMENT.

GRADING UP.

The process of improving native stock by breeding the females to purebred males is termed grading up. The first cross is usually a

Value of Pure Blood.

Fig. 23.—Barred Plymouth Rock male used for the first cross on mongrel hens such as the one shown in the preceding illustration.

Value of Pure Blood.

Fig. 24.—First-cross pullet of mongrel hen shown in figure 22 and sired by male shown in figure 23.

Value of Pure Blood.

Fig. 25.—Second-cross pullet. Size, conformation, and color of pattern have been greatly improved.

Value of Pure Blood.

Fig. 26.—Third-cross pullet. Fanciers who did not know how she was bred would call this pullet a good representation of the breed.

very noticeable improvement over the native stock. When the females of this mating are bred to a male of the same breed, greater

fixity of type appears. Continued use of males of the same breed results, in a comparatively short time, in animals which are practically purebred, although not eligible to registration and therefore not salable as purebreds.

In grading up, consistent methods should be used and males of the same breed used, cross after cross; otherwise the stock will be mongrelized instead of improved. Males should also be better individuals in all respects than the females with which they are mated, in order that each successive cross may be an improvement over the ones which went before it.

Uniformity Quickly Obtained by Use of Purebred Males.

FIG. 27.—Kids at the Experiment Farm of the Bureau of Animal Industry, Beltsville, Md., by purebred Saanen bucks on foundation of native does.

CROSSBREEDING.

Crossbreeding is the mating of purebred animals of different breeds of the same species. Crossbred animals are usually larger and more vigorous than either parent. Their hereditary material, however, is so complex that there is no certainty as to what results will come from mating them. Except to produce market animals, crossbreeding should be used only by the highly skilled breeder, and it is not practicable in his case unless he has an opportunity to place the progeny on the market for breeding purposes. American practice in livestock breeding does not encourage the development of new breeds except in the case of poultry and pet stock. Therefore the practical man, as a rule, will leave this matter to the experimentalists.

SOME INCORRECT IDEAS OF HEREDITY.

From the earliest beginnings of rational mental processes human beings have asked the question "Why?" Failing to receive an answer concerning things which they could not understand they have theorized and developed explanations as a result of such theories which often have not had any basis in fact. From the time when the simple shepherds of Asia watched their flocks beneath the stars and wondered at the mysteries of nature around, above, and beneath

A Fast-Disappearing Type.

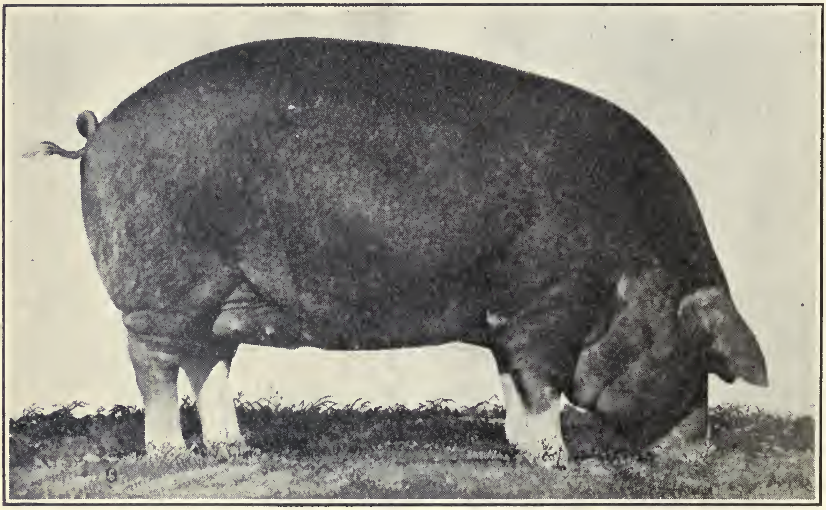
FIG. 28.—Native Piney-Woods sow. Note the wattles. These sows are prolific, good milkers. and good mothers. In other respects they have nothing to commend them. Purebred sows are just as prolific, just as good milkers and mothers, and make pork far more rapidly and more economically.

them, man has marveled at the mysteries of heredity. In some form or other many of these meditations have persisted until modern times as beliefs for which no unassailable proof has ever been presented.

TELEGONY.

These beliefs are sometimes intensified by an apparent confirmation from scientific sources. Possibly the most outstanding instance of this kind is the famous case of Lord Morton's mare, which in the opinion of the great Charles Darwin confirmed the theory of telegony.

This theory was that the first male to impregnate a female permanently endowed the female with his characters, so that subsequently she would always exhibit them in her progeny. If this male was of another breed the female became a crossbred by means of this first impregnation. The Lord Morton mare was a Thoroughbred; she was mated with a quagga and produced a hybrid foal. She was then mated to a Thoroughbred stallion and produced a foal with stripes. In spite of the fact that Darwin knew that frequently horses had both shoulder stripes and leg stripes, and that mules with leg stripes were known to occur, he coupled this Morton case with the erroneous beliefs of dog breeders and gave the theory in question the powerful support of his authority. The theory has been completely disproved by Ewart, who has clearly shown it to have been



Purebred Poland China sow.

FIG. 29.—Contrast this picture with the photograph of the Piney-Woods sow.

a manifestation of inheritance. Horses, asses, and other equine stock have a common origin. With our present knowledge of Mendel's law, which was unknown to Darwin, we can understand much more readily that the appearance of stripes in horse stock is more likely due to the unexpected appearance of a recessive character than to any residuary effect of any impregnation on the chromosomes of the female germ cells. Such a theory is utterly impossible if we accept the known facts regarding the chromosomes and their behavior.[7]

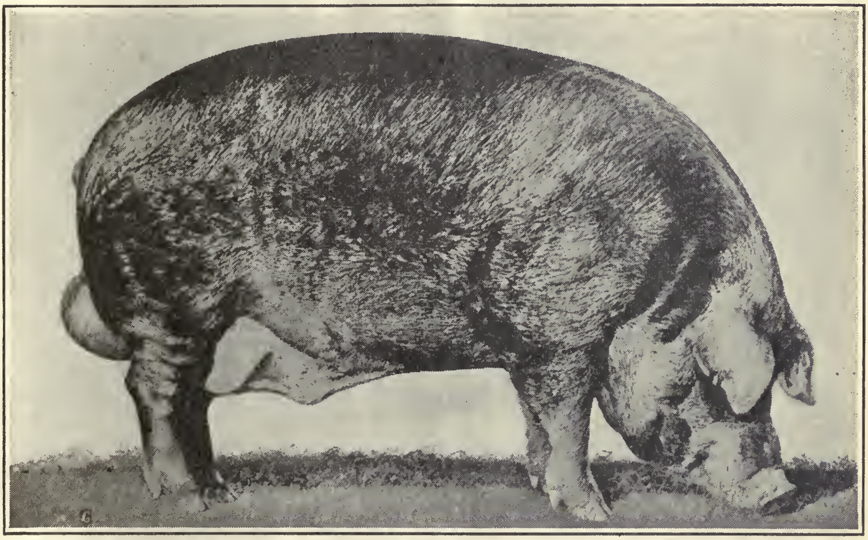
Crosses most readily demonstrate the operations of Mendelism, and the more violent the cross the more astonishing are the results. It often happens that the cross of ass and mare brings to the surface characters common to the horse ancestors of the distant past. Another interesting case is seen in crossing certain breeds of hogs, re-

[7] See pages 5–8.

sulting in young which have the longitudinal stripes characteristic of the young wild boar.

MATERNAL IMPRESSIONS.

A famous ancient classic is the bargain which Jacob made with his father-in-law Laban, and since its historic consummation some breeders of cattle have believed that the presence of objects of striking form or color before the eyes of the female at the time of conception have an influence on the characteristics of the progeny. So far as the Biblical case is concerned, the writer's impression is that Laban was not so skilled in the animal husbandry of his day as was



Purebred Duroc-Jersey boar.

FIG. 30.—Quick results can be obtained by using such males on native sows, or an investment may be made in one or two purebred sows, from which an entire herd of purebreds is soon at hand.

his crafty son-in-law, and judging by what we know to-day of the livestock of Palestine, it would have been far more remarkable if a large proportion of the calves had not been speckled and spotted.[8] A much more modern case is that of McCombie, of Tillyfour, one of the early Scotch improvers of Aberdeen-Angus cattle, who is reported to have believed that he could increase the proportion of black cattle in his herd by having his barns and fences painted black. The red color was comparatively common among Angus cattle a hundred years ago, and breeders were constantly culling out that color. From what we now know of the action of the chromosomes, it was selection and not the color of McCombie's barns that made the Angus cattle "black and all black." Even to-day an occasional red Angus calf appears, as we would expect to happen according to the Mendelian

[8] See Genesis xxx : 25–43.

law of inheritance. If the color before the cow's eyes at the time of service had anything to do with the color of the calf, the red barns of the Corn Belt would long since have had an astonishing effect on our American Angus cattle.

Even monstrosities in animals are probably the appearance of some long-submerged character, brought up out of the stream of inheritance by some peculiar combination of the hereditary elements. Certain animals and certain strains produce monstrosities more often than others. Many of these can be brought out readily by intensive inbreeding.

The pregnant mother, whether of the human or of the animal family, should be an object of the utmost solicitude and should receive the most thoughtful, tender care. She is engaged in a double duty. The development of the young creature in her body taxes

How Good Breeding Affects Size.

FIG. 31.—The large animal is a yearling Aberdeen-Angus steer. The smaller one is a three-year-old Piney-Woods steer. The difference between the two is due almost entirely to difference in breeding.

both bodily strength and nervous organization. We must not forget, however, that there is no direct connection of circulation or nervous system between the mother and the fetus. Therefore the fetus can not be affected by what the mother sees or hears. Accidents to the mother, however, such as sudden strains, falls, etc., may have effects resulting in the serious injury or death of the young. These, again, are not due to heredity, no matter what the effect on the young may be.

CONCLUSIONS.

The writer does not presume by any means to believe that his effort will succeed in removing completely from the minds of men their fallacious beliefs concerning animal inheritance, but he does hope that he may have some influence in causing those who breed animals to look more to nature herself and to the operation of her

laws for the explanation of the facts which they observe and not try to explain them as due to supernatural causes. To summarize very briefly, let us bear in mind the following fundamental facts:

1. All animal forms on the earth have developed gradually from lower forms by very slow changes. This is the process known as evolution.

2. The young animal starts on its career when two bits of hereditary material (germ plasm) unite, one from the female (the egg) and the other from the male (the sperm). When the union is complete, the sex, identity, and individuality of the animal are settled. Chance plays a most important part in determining these factors.

3. From now on the fate of the animal depends on its nourishment and environment.

Why Cloud a Boy's Dreams With This Kind of Stock?

FIG. 32.—Give the youngsters well-bred pigs, calves, sheep, and chickens, and they will be much more likely to stay on the farm and become producers of useful, profitable animals to the advantage of their own pocketbooks and the wealth of the Nation.

4. The breeder can do much to bend the operations of the laws of chance to his own ends by careful selection of breeding stock. "Breed the best to the best."

5. Next to selection the best means at the command of the breeder to fix type in his animals is inbreeding. It is a powerful tool, but a dangerous one in unskillful hands. Inbred sires are more impressive as a rule than sires which are not inbred.

6. Nature does not work lawlessly. Occurrences attributed to supernatural means can be more rationally explained as a manifestation of some operation of a law of heredity.

If a breeder has a clear conception of these facts, he can usually explain by one or the other nearly every occurrence which he may observe. The clearer he thinks on these subjects the more successful he will be as a breeder.

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